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EFFECT OF THE PROCESS PARAMETERS OF MIX PREPARATION ON THE PROPERTIES OF FOAM GLASS

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A method of preliminary briquetting of a foam glass mix using water as the technological binder is examined. The regime parameters for the preparation of foam-glass mix are determined. It is established that hydration and hydrolysis of the glass improve the conditions for the expansion of foam glass and improve its physical-technical properties.

Key words: foam glass, cullet, briquetting, technological binder, water.

Effective heat insulation is becoming increasingly important in construction. A material that best meets the requirements of the construction industry is foam glass, favorably distinguished with respect to all properties from materials such as polystyrene foam and polyurethane foam [1].

The production of foam glass is a quite complex and energy-intensive process. There are a number of drawbacks to the conventional technology for obtaining foam glass by the powder method; one is the high metal content of the production process. Preliminary briquetting of foam glass mix makes it possible to eliminate molds, and an important factor of the technology is the choice of the type and amount of technological binder.

A mixture of finely ground colorless cullet (S_{sp} = 4654 cm^2/g) and a gas producer, which consisted of dolomite ($CaMg(CO_3)$) (S_{sp} = 2517 cm^2/g) used in the amount 3 wt.%, were used as the components of the foam glass mix.

The chemical composition of the cullet was as follows (wt.%): 73.4 SiO_2, 0.5 Al_2O_3, 6 CaO, 3 MgO, 16.5 Na_2O, and 0.5 SO_3.

Combined comminution of the cullet and dolomite was performed by a centrifugal-impact method, whose advantage over milling in a ball mill consists in 20 – 30% lower energy consumption and production of powder with a narrow size range with particles of high defectiveness and uniform shape. This permits briquetting with minimal consumption of the technological binder.

Cylindrical samples, 50 mm in diameter and 50 mm high, were formed from the foam glass mix, obtained by careful mixing of the required components with the technological binder by means of bilateral pressing under pressure 45 MPa. The expansion was conducted in a laboratory chamber furnace at 750°C, the heating rate was 4.8 K/min, and the soaking time at the maximum temperature was 30 min.

It was determined on the basis of previous studies [2] that foam glass with high porosity can be obtained from cullet by using liquid glass as the binder. However, a liquid-glass binder is not always effective, since rapid foaming occurs on heating and dissipative phenomena appear in the system (enlargement and collapse of pores), which creates a problem in regulating the pore structure of the material.

These drawbacks can be eliminated by using water as the technological binder. The binding capacity of water is due to hydrolysis and hydration of the glass. Water binds structurally with glass and in the form of $(OH)^-$ groups covers the surface on which sorption of new portions of water occurs, which forms depending on the course of the reaction a layer ranging in thickness from several tens to even hundreds of molecules [3].

In addition to undergoing hydration the glass also undergoes hydrolysis with formation of an alkali according to the scheme

$$R_2OnR_xO_y + m_2H_2O = 2ROH + nR_xO_y + (m_2 - 1)H_2O. \quad (1)$$

Aside from a binding function the presence of water in the foam mixture lowers the viscosity of the melt formed during expansion. The decrease of the viscosity is due to $(OH)^-$ ions being incorporated into the structure of the glass network; these ions break the continuous chain of the network into individual links [3].

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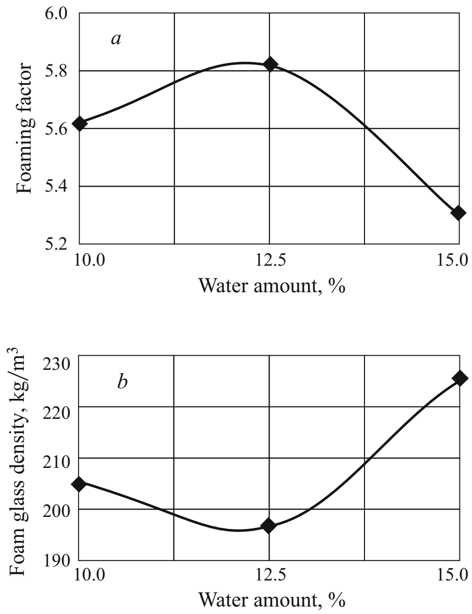

Fig. 1. Effect of the mass content of water on the degree of increase of the volume (*a*) and density (*b*) of the foam glass obtained.

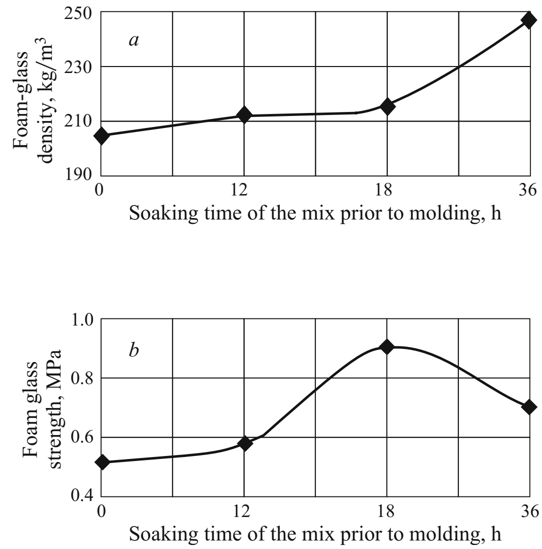

Fig. 2. Effect of the soaking time of the mix prior to molding on the density (*a*) and strength under compression (*b*) of briquettes and the foam glass obtained.

The bound water in the foam-glass mix, or the partial pressure of the water vapor, affects not only the decrease of the viscosity and the surface tension of the initial glass but also the onset temperature of the gas forming reaction (which was 700°C). For this reason, it can be assumed that the presence of bound water in the sinter increases the thermodynamic probability of gas-forming reactions with a simultaneous drop of their onset temperature to lower values. Since the viscosity of the melt also decreases in the presence of the $(OH)^-$ groups, the process of foaming of foam glass also starts at a lower temperature.

For briquetting, i.e., pressing of the foam glass mix, it is important to find the optimal moisture content, since an excess of binding liquid during agglomeration is just as undesirable as a deficit. For this reason, a problem considered in the present work was to determine the optimal amount of water.

The introduction of moisture into powered material even without application of external pressure promotes compaction of the material as a result of water surface tension forces pulling small particles together. As the binder content in the powder increases, the compaction of the powder becomes more intense at lower pressing pressures, since the water wets and separates the particles, decreasing the friction between them. However, the density can increase with increasing moisture content in the powder up to a moisture content that corresponds to the pressing pressure.

The effect of the amount of binder on the density of the foam glass was evaluated according to the foaming factor (Fig. 1).

It follows from Fig. 1 that the foaming factor reaches its maximum value at binder content 12.5% — the volume of the briquette increased 5.82-fold. As the amount of the binder continues to increase, the foaming factor decreases, which can be explained by the development of pore coalescence as a result of a decrease of the viscosity of the molten glass. Likewise, binder content above 12.5% increased the foam-glass density. In addition, the samples obtained from briquettes with binder content 15% contained pits and cracks through the entire volume.

To ensure rational foaming conditions not only is a uniform moisture content in the mix required but so is hydration, i.e. soaking of the foam-glass mix before molding.

It was established that when silicate glasses (with high SiO_2 content) dissolve the alkali-metal oxides dissolve more quickly than SiO_2, as a result of which a silicic acid gel film forms on the surface of the glass grains and slows the reaction. Dilution of the solution of alkali silicate with water (adding new portions) further increases the SiO_2 gel film, as a result of which the dissolution of the glasses slows down [4]. Therefore the glass hydration process must be conducted with minimal moisture content in the glass or under conditions which preclude an increase in the thickness of the protective films which form and, evidently, have negligible water permeability. Since soaking a foam glass mix prior to molding promotes the formation of water films on the surface of the glass grains as well as their hydration, it is useful to determine the optimal soaking time.

Figure 2 shows the effect of the soaking time of the mix prior to molding on the density and strength of the foam glass obtained.

For mix soaking time up to 18 h prior to molding the density of the foam glass remains constant, i.e., an optimal number of water films form on the glass-grain surface, which

Fig. 3. Structure of foam glass obtained from briquetted cullet on water binder.

promotes the formation of foam glass with a uniformly organized structure.

Soaking of the glass foam mix in a moistened state for longer than 18 h is undesirable, since further hydration of the glass grains increases silicic acid and water films, which slows down the dissolution of the glass, has a negative effect on the structure, and promotes an increase of the pore size and hence results in the degradation of the service properties of the glass.

Therefore, hydration and hydrolysis of glass, which occur during soaking of the foam glass mix, have a positive effect not only on the decrease of the viscosity of the sinters of the foam-forming mix but also expand the temperature range in which the foam glass structure develops. Thus, the melt becomes "long," which gives foam glass predominately with blind porosity (Fig. 3).

The use of 12.5 wt.% water as the technological binder with the foam glass mix soaked in a moistened state for no more than 18 h prior to molding makes it possible to obtain a foam glass of high quality: density 205 kg/m^3, ultimate strength under compression 0.9 MPa, and water absorption 2.34 vol.%.

In summary, the method of briquetting foam glass mix on a water binder is cost-effective, because mix preparation is less expensive, metal-intensive molds are no longer needed, and the foaming temperature of the foam glass mix is lower.

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